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Inside . . .

Insulation 3
How is effectiveness of insulation measured? 4
Insulation Materials 5
Effective Insulation Value and Building Performance 7
House Performance Study 7
Structurally Insulated Panel versus Conventional Frame Houses 7
Technical Research Committee News 8
What Is the Cost of Tankless Residential Hot Water Heaters? Home Rating Update; Calling All Builders; BC Super Efficient New Construction Program
Proposed Energy Efficiency Regulations for Residential Boilers 9
CSA P.10-07 Standard: Performance Of Integrated Mechanical Systems For Residential Heating And Ventilation 10
Matrix: Integrated Mechanical System 11
Vancouver's Greenest City Initiative 11
Comings and Goings: Changes at NRCan 13
Side wall vented gas appliances 14
R-4 Insulsheathing: Insulated Sheathing 15
Energy Answers 16
You Asked Us: About Finishing a Basement Bathroom 17
Nanoscience for Greener Concrete 18
Net-Zero Energy Home Awards 19

Insulation

From The Editor . . .

I was going to write a commentary based on a couple of presentations made at the 12th Canadian Conference on Building Science and Technology in Montreal in May. The basic theme of the speakers was that when considering cost paybacks, we shouldn't be looking at short-term impact on our pocketbook. Rather, we should be looking at it as borrowing from future generations, so a long-term view is needed.

However, as I was thinking about it, I came across a piece in the current issue of Walrus magazine (An Inconvenient Talk, Walrus, June 2009, *www.walrusmagazine.com*) that astounded me. I urge everyone to take a look at it.

The article describes a talk David Hughes gives. He is a retired research geologist who worked for many years at the Geological Survey of Canada (a branch of Natural Resources Canada). He is no wild-eyed tree hugger, loony leftie or someone on the fringes. Rather, as a geologist, he understands the facts and research reports of the geological world.

His stock in trade was the evaluation of geological records. As he weaves them together, a remarkable picture comes up. In his analysis, Al Gore and the International Panel on Climate Change come across as optimists.

Hughes notes that the idea of peak oil – the moment when we have consumed half the planet's oil reserves which has been ridiculed by the oil industry – has been around since it was first formulated in 1956. As late as 2005, the International Energy Agency was dismissing the concept, but in 2008 they started to take a closer look at available hard data and started to back-pedal their denial of peak oil. Privately some oil industry executives have been concerned for a while.

The data that has been identified for all to see, if they care to, is that 90% of all oil humans have used has been burned since 1959, 50% since 1986. Ninety percent of all natural gas consumed has been burned since 1964. Even coal, which has been assumed to be available in vast quantities, has finite limits – half of recoverable coal has been used since 1972. An analysis of available coal reserves suggests that they are not as numerous nor as rich as some suggest.

The point is that we should not be looking at separate energy types (oil, gas, or coal), but rather at hydrocarbons as a whole since in the end they will be used interchangeably. Current estimates are that we've consumed about 40% of all recoverable hydrocarbons. At today's consumption rates, 80% will be gone by 2050!

One consequence is that because of limited supply, the worst-case scenarios of CO_2 levels in the atmosphere may not happen simply because there is not enough coal to burn!

And as consumption of readily accessible hydrocarbons carries on, it increasingly becomes more difficult and expensive to extract the remaining. And what will remain for future generations?

The more serious implications are the impacts it is going to have on all of us. If we think the economy is in trouble today, think of the impacts when there are no hydrocarbons available, at any cost. Think of a world without oil and gas – it may happen within the lifetime of many readers.

Perhaps not enough serious attention is being given to the realities because there are too many economists and politicians and not enough geologists! At the rate decisions are not being made, the government's inaction will be irrelevant.

What are we leaving for future generations? I don't think we're borrowing from them – we're stealing it!

Richard Kadulski,
Editor

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Insulation

Why Insulation?

We live in an inhospitable climate. Our ancestors learned to build shelters to protect us from the elements. Over time, we've learned to make buildings more comfortable by conditioning them. The colder, more severe the climate, the more important this becomes. In the past, even though they provided shelter from the elements, many structures were poorly insulated and were uncomfortable at some times of the year. Conditioning was achieved by simply burning more fuel with the hope of keeping the home comfortable, and in summer, simply moving outdoors, or living on covered porches.

In the past people wore clothing as an added layer of personal insulation. There was summer clothing and winter clothing. There is a reason why traditional clothing from cold climate locations is heavy and floor length, while that from tropical climates is a scanty wrap. The heavy floor length coats, smocks and skirts made of heavy fabrics and woollens were designed to keep the wearer warm in cold weather. It was personal portable insulation.

Today, we have highly developed mechanical systems that can condition any building in any location – you only have to throw enough mechanical equipment and be prepared to pay for the energy. That is why glass boxes are seen in all parts of the world, regardless of the climate – it just takes more or less energy to keep the building habitable.

Today there is one certainty – energy prices are not going to come down in the future. We are at peak production for petroleum-based fuels, and our aggressive use of fossil fuels is dangerously changing the planet's climate. It is now clear that we cannot keep on generating more greenhouse gases to condition our buildings. We need to ensure that building energy consumption is reduced.

Energy efficient high performance building envelope design and construction can drastically reduce the building's energy consumption. It is possible in most of the country to build homes that, for all intents, do not need a furnace to keep comfortable. It simply requires the will to do it and attention to the construction details and specifications. Increasingly, more builders and owners are looking to do this. Key is to reduce heat flow out of the building.

Heat flow depends on ever-changing temperature conditions. Heat flow is three-dimensional and varies over time. In addition, the thermal storage capacity of some materials will also affect the performance. For practical reasons, heat flow is considered to be a one-dimensional, steady state flow through homogenous materials. In reality, heat flow is more complex than that.

To design and build an energy-efficient home requires an understanding of how heat flow can be controlled.

Heat flow occurs by three mechanisms:

- **Radiation** – heat flow by electromagnetic waves through a gas or vacuum. This requires a clear line of sight – it is how the sun heats the earth, or a wood stove heats a person in a room.
- **Convection** – heat flow is by the movement of molecules in a fluid such as air or liquid. As the fluid is warmed, it becomes less dense and as it rises it is displaced by cooler fluid surrounding it. This is how a baseboard heater heats up a room as the air is slowly circulated around it.
- **Conduction** – heat flow is through direct contact of materials and happens when materials are in direct contact. This is how heat flows through framing and other solid materials.

Heat flow is complex and will embody all of the primary mechanisms at any given time. It is also dependent on the moisture content of materials through which it flows.

Insulation products

All materials in a building have some resistance to heat flow. Some are better resistors than others – these are called insulation. Still air by itself is a good insulator, but when there are differences in temperature, and the air space is large, convection currents occur, which thus can move heat. That is why most insulation products are lightweight materials with a large proportion of air pockets. With porous insulation materials, all three modes of heat transfer can occur simultaneously.

How is effectiveness of insulation measured?

R-value is a measure of the ability of a material to resist heat flow. It was developed more than 50 years ago to provide an easy to compare measure of insulation performance. This is the most common term used in North America – it is simple to measure and easy to understand.

Heat flow can also be referred to by the U-value (or U-factor), which is a measure of the overall heat transfer coefficient, and is a term used in much of the rest of the world. It describes how well a material or building assembly conducts heat. The U-value is the reciprocal of the R-value (i.e. U = 1/R). The higher the R-value, the better the insulation. Conversely, a smaller U-value is better.

Thermal performance testing began in earnest in the 1940s, and took on greater importance in the 1970s with the first energy crisis.

Insulation performance is derived in laboratory tests that measure the rate of heat transfer through a material or assembly under standardized conditions. The test is a static, single condition test with set temperatures and temperature difference across the insulation.

The testing apparatus is referred to as the "guarded hot box". The insulation material is installed into the assembly, and a known temperature difference established across the material. Instructions for the preparation of test specimens are spelled out in testing standards. Standard tests use a temperature difference of 24°C, at 50% humidity with no air movement, even though for some applications, a greater temperature difference would be more appropriate.

Some product manufacturers use their own testing protocols to help them stretch the truth about the insulating value of their product. That is why the US Federal Trade Commission developed the "R-value Rule" to govern claims about insulation R-values and protect consumers against deceptive and misleading advertising claims. The Rule mandates that specific R-value information for home insulation products must be disclosed in ads and at the point of sale, and that the claims must be based on established, credible test standards.

R-Value is an accurate and reliable expression of how insulation materials perform in a laboratory apparatus, but buildings don't live in laboratories. They have walls and ceilings, and experience a variety of climatic conditions. In the real world of buildings R-Value is only one factor in the actual performance of insulated building assemblies. In the real world, things are much more complicated.

For 30 years this US rule has attempted to provide a level playing field for competitors and useful unbiased information for consumers. It has significantly reduced misrepresentation and outright fraud in the insulation industry, however, changing technology, better scientific understanding, practical field experience, heightened performance expectations, and a range of new products and systems have exposed some of the limitations of the R-value Rule.

Although the nominal R-value of the insulation is important to ensure that buyers receive the insulation they contract for, it is the system performance that is equally important. The system performance takes into account more of the three dimensional heat flows and all the heat transfer mechanisms.

Because it is difficult to categorise this system performance, insulation manufacturers can once again confuse the issue as each one states that their product is better. They downplay the negative aspects, and highlight the positives of their product.

Some have gone so far as to try and monitor the performance of similar houses that were built with different materials. Industry literature contains a number of examples, highlighting tests done in various locations, by various schools or labs that monitored similar homes. The challenge is to be certain that the comparisons are really measuring the same things. We know that energy performance can be influenced by many things, not just insulation and how it was installed, but also by occupant habits, temperature settings, interior gains (lights, appliances), air-tightness of the building, etc.

These comparative tests do provide an indication of the performance, but unless they had followed very rigorous monitoring protocols, they are only approximate performance values, and are not as definitive as the proponents would like to claim.

One significant contributor to the overall building performance improvement that is not captured by the guarded hot box testing of insulation materials is air-tightness. Systems that improve the air-tightness of the building can help improve the building's performance. Another is the thermal bridging through a building assembly.

In recent years a broader range of insulation materials and application methods have been developed than were available when the R-value was developed. Some of the new building products and systems include various types of spray foam and spray-applied fibrous insulations, exterior insulated sheathing, Exterior Insulation Finish Systems (EIFS), Structural Insulated Panel Systems (SIPs), Insulated Concrete Forms (ICFs), and Radiant Barrier Systems. These systems all control heat flow in different ways and are often more than just insulation.

Manufacturers of rigid insulation products (either board stock or spray foam) point out their systems can perform closer to the rated R-value because the insulation is inherently airtight, thus minimizing the convective heat loss due to air circulation and moisture flows through a conventional frame wall, especially when compared to batt insulation installed in a haphazard manner that allows for voids in the assembly.

R-value or ?

Classification of insulation performance should include a number of factors, including:

- The effective thermal conductivity of insulation materials across variations of temperature
- Effect of settling and off-gassing of materials.
- The influence of thermal bridging of structural components.
- The susceptibility to construction defects that can result in convective loops
- Air leakage and wind washing and
- Thermal storage capacity of materials.

Some of these factors can be controlled by the building design, and their influence on thermal performance is predictable (e.g. thermal bridging). Others, such as convective loops and air leakage are the result of a combination of design and workmanship. Their impact on performance is more difficult to predict.

Insulation Materials

A variety of materials are used for insulation. Each has its unique properties, and will perform when used appropriately. Essentially, whatever the product, they work by providing a matrix of air pockets. How these pockets are manufactured depends on the properties of the material.

Fibrous

Fibreglass

Fibreglass is made from fine glass fibres, which trap air within the fibers making it a good thermal insulation material. The technology for mass-producing it as insulation material was invented in 1938 by Owens-Corning.

Today, much of the fibreglass produced uses post-consumer recycled glass as raw material. It is usually made into batts used in wall and ceiling applications. It is also available for loose fill applications, which are commonly installed in flat ceilings over the ceiling drywall.

Cellulose

Cellulose insulation is made from recycled newsprint and other paper sources – paper that might otherwise end up in landfills. It is a loose fill product normally used in flat ceiling applications. It can also be installed as a spray-in place insulation product but these applications require either a mesh across the face of the studs to contain the material, or a binder added to the cellulose to allow it to set up in place.

Cellulose is a more dense material than fibreglass, so claims are often made that use of cellulose will help air seal the house. This is not entirely correct, although the higher density does contribute, when installed correctly, to a more consistent material density and a slightly higher insulating value per inch thickness.

Wool

Insulation batts made from wool have recently appeared on the market. Sheep wool is a natural, sustainable product. Wool is an effective insulating material, which is why it has been used for years as clothing (especially winter clothing – think sweaters, scarves, toques, tweed coats). Its insulating performance is similar to that of fibreglass.

Cotton

Batts using recycled fabrics have recently been developed. These are similar to wool batts, except that rather than sheep wool, post-consumer fabrics are used, much of it old jeans.

Vermiculite

Vermiculite is a natural mineral that expands when heated to high temperatures.

It is a non-combustible material used as loose fill insulation. Although it is an effective insulation, vermiculite originating from a mine in Montana (and marketed under the Zonolite brand) has been found to contain small amounts of asbestos.

Straw

Some green builders and designers have become enamoured of straw-bale construction as a building method. Straw bales can be used as structural elements, insulation, or both. However, the climate and building design need to be considered when straw is used.

Cellular Foams

Several cellular foam products are used for insulation.

Manufactured boards

- **Expanded polystyrene** (EPS) is made by expanding polystyrene pellets with steam injection into a mould. These are often referred to as 'bead-boards'.
- **Extruded polystyrene** (Styrofoam) is manufactured by the extrusion of heated polystyrene with a gaseous blowing agent through a mould to create slabs of high-density foam boards.
- One is an **open cell** ('half-pound') product that is lightweight, has a high ratio of expansion, and an R-value similar to that of cellulose.
- The second is a **closed cell** ('two-pound') that has a higher R-value, and when set resembles extruded polystyrene.

Typical Insulation Material Properties

Material	R-value Per inch thickness (RSI)
Fiberglass *Available as batts or loose fill for blowing*	3.4 (0.59)
Cellulose	3.6 (0.62)
Cotton	3.4 (0.59)
Vermiculite	2 (0.34)
Straw	2 (0.34)
Expanded Polystyrene (EPS)	3.6 – 4 (0.34 – 0.69)
Extruded polystyrene (XPS)	5 (0.87)
Spray foam – open cell ("half-pound")	3.8 (0.66)
Spray foam – closed-cell ("two-pound")	6 (1.05)
The blowing agents for spray foam are being changed, so the R-values for many products may be reduced. The net R-value for these products increases slightly with the thickness. This is referred to as the Long term thermal R-value (LTTR)	

Spray foam insulation is blown on-site against other building materials. On expansion and setting, the foam adheres to all surrounding materials forming an airtight assembly. Two types of spray foam are commonly used in construction.

Reflective foils

Unlike bulk insulation products, reflective foils have a high thermal conductivity and function poorly as a conductive insulator. Radiant barriers retard heat flow by reflecting radiant energy away from its surface or by reducing the emission of radiation from its opposite side. Their value in most residential construction is limited.

Calculating the performance of radiant barriers is more complex than for conventional bulk insulation products. The tests and procedures to evaluate bulk insulation are not applicable to radiant barriers, so radiant barrier distributors rely on their unique testing to generate 'equivalent' R-values. In the process, they have generated controversy and confusion in the building industry, and mislead many.

Radiant products have entirely different systems of inhibiting heat transfer so that looking for 'equivalent R-values' is inappropriate. Radiant barriers have high reflectivity (and low emissivity) over a range of the electromagnetic spectrum (including visible and UV light), but their thermal advantages are mainly related to its emissivity in the infrared range. Rather than R-values, the emissivity value is the appropriate metric for radiant barriers.

Vacuum panels

New products are being continuously researched and evaluated. One interesting product that is being tested in prototype applications at this time is vacuum panels. These have very high R-values in very thin panels. They are relatively fragile and mishandling could destroy the panel, however, there may be special applications where it may be worth considering such products. Commercialisation, however, is still some years in the future.☼

Effective Insulation Value and Building Performance

Measured insulation value of a material by itself is only part of the story because it is a laboratory derived value under controlled conditions. Conventional practice is to refer to the nominal R-value of the insulation as the insulation level of the construction assembly in which the insulation is placed. Thus, a 2x6 frame wall with R-20 batt insulation is typically referred to as an R-20 wall.

However, in a typical wood frame wall, heat flow is stopped not just by the insulation, but also by the studs, except that the insulating value of wood studs and other framing elements is much lower than that of the insulation – a typical 5½" stud has an R-value of about 6.5, compared to a fibreglass batt that has an R-value of about 20. Since wood framing accounts for about 19-25% of the total surface area of a typical wall, the effective R-value of the entire wall, when the two values are averaged, will be substantially less than the nominal R-value of the insulation. That is why it is much more important to know how a product fits into the whole construction assembly, and to determine its effective R-value.

Alternate construction assembly manufacturers are using this to their advantage in the R-value wars.

Insulated concrete forming manufacturers are pointing out that there is no framing to create thermal bridging, so that their effective R-value is much higher. Their claim of R-22 to R-24 is shown to be much better than the effective R-16 of a conventional 2x6 frame wall. Monitored results suggest a typical ICF wall insulation is very close to that of the nominal insulation value of the polystyrene layers of insulation.

The structural insulated panel (SIP) industry is similarly pointing out that, since a typical SIP panel is composed of rigid EPS insulation with a minimum amount of framing members, it has a much higher effective R-value.☼

House Performance Study Structurally Insulated Panel versus Conventional Frame Houses

A Brock University (Ontario) study looked at two rental houses located side by side. Both buildings were identical in design and had similar east-west orientations, ensuring the same exposure to outdoor temperature and wind conditions. Except for brief periods, both houses were occupied throughout the study, which took place over a 12-month period from February 2000 to January 2001. Both units were heated with a natural gas fired forced air system.

One unit was constructed with 4.5" thick structurally insulated panels (SIPs), while the other used 2x6 studs with batt insulation. Both houses were built to comply with the Ontario Building Code by the same crew, who were not aware that testing would be conducted afterwards.

The study incorporated several test methods to analyze different determinants of energy efficiency: thermographic imaging, hourly temperature readings and air leakage measurements.

Temperatures were taken in the middle of the wall and on the interior and exterior of the wall. The stud construction showed the greatest fluctuation in temperature at the mid-point of the wall, corresponding closely to the outdoor ambient temperatures, especially between December and February. The temperature difference between the interior wall surface and the exterior wall surface over the course of the year was lower for the SIP wall (an average of 6.5°C) compared to 12.3°C for the stud wall.

The SIP wall sensors recorded higher and more stable temperatures at those locations. The temperature of the middle wall sensor averaged 1.95 ºC (35.5 ºF) for the stud wall, while the SIP wall averaged 15.61 ºC (60.1 ºF) in January.

These variances are important because heat will move from warm to cold, so the higher temperature in the middle of the wall indicates that the SIP wall experienced less heat loss than the stud wall.

The results of the air leakage tests showed the SIP house was much tighter than the stud house. The SIP house measured 1.55 ACH (air changes per hour) at a pressure differential of 50 Pa, while the framed wall house was 2.60 ACH at 50 Pa. ☼

Canadian Home Builders' Association

Technical Research Committee News

What Is the Cost of Tankless Residential Hot Water Heaters?

CMHC is about to do a study to determine the range of energy and cost savings attributable to tankless water heaters. The study will aim to look at 50 to 100 homes that are going to change their conventional water heaters to a tankless water heater. The energy use by existing water heaters before they are changed will be established. Equipment and installation costs will be recorded, and post installation energy costs will be monitored.

Calling All Builders

There are a number of issues that are going to be looked at in the next code cycle, such as snow load requirements, EIFS, and energy efficiency requirements. Other issues come up from time to time as standards are reviewed and updated.

There is a constant discussion about what represents 'minimum' standards, what represents best practices, and what may be appropriate upgrades to help advance general performance standards. It is important to note that changes are seldom made in isolation, rather they are done in consultation with stakeholders. There are plenty of opportunities for industry input but you have to give it.

There is a constant need for individuals to participate on task groups and committees. Time commitments depend on the issue, and some issues are dealt with by conference calls and e-mail, so do not always entail extensive travel commitments. If you are able to participate, let CHBA-TRC know, including the topic areas you have an interest in, and they'll forward your name to the appropriate agencies as opportunities arise. Participation can be very rewarding.

Remember, next time there is a change in regulations that you disagree with, you could have done something about it!

The Technical Research Committee (TRC) is the industry's forum for the exchange of information on research and development in the housing sector.
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Home Rating Update

At what point do home ratings become mainstream? Since its inception in 1998, more than 500,000 Canadian homes have been Energuide rated. Since the program was modified and renamed ecoEnergy (in 2007) more than 247,000 homes have been rated. The total number of houses evaluated now represents about 5% of the total number of houses in Canada.

Although this is primarily an existing houses program, more than 20,000 new homes have been labeled as the rating is used in regional building programs, such as Built-Green and the Power Smart new home program.

These numbers are going to increase significantly as regulations are introduced requiring a label before any residential sale can go ahead (either new or old). This is being put into place in Ontario, and it is expected that BC will be following soon.

The ecoEnergy program is having a significant impact as many homeowners are undertaking upgrades. In the last two years more than 80,000 homes have been upgraded, improving energy efficiency by an average of 23%. The improvements average 10 ERS points, and represent a greenhouse gas reduction of about 3.3 tonnes per house per year.

Most common retrofit measures are upgrading heating systems and air sealing, followed by insulation upgrades and window replacements.

BC Super Efficient New Construction Program

Following on the ambitious energy policy established by the provincial government, the BC government will be supporting the construction of 100 homes and an educational building that will try to achieve net zero or near net zero energy performance.

Passive design, including superior building envelope construction and passive solar gain through building orientation, is the primary design concept being encouraged on the path to net zero homes. Other design considerations will be the use of clean community energy sources and on-site clean power, heating and cooling supplies that supply as much energy over a year as purchased from utilities.

These buildings will be the most energy efficient ever constructed in British Columbia to minimize the need for purchased energy. A desirable outcome (but not required) would be that they also achieve "net zero community energy" status through the generation of heat and power from on-site or community-based, clean energy resources.

A key focus of the project is to construct marketable homes that achieve a superior energy rating, primarily through advanced envelope construction, passive solar design and super-efficient energy-using equipment within the building. A marketable home is defined as one that is technically and financially feasible to construct, has a design and a market price that would be considered desirable by a reasonably broad range of consumers and has a design that is replicable by builders and the trades in BC.

The funding will provide a contribution towards the incremental capital costs required to achieve net zero or near net zero energy homes. This is not intended to build a few "one-off" demonstration homes – each project must include a minimum of five units.

The energy rating requirements are:

- A minimum EnerGuide rating of 90 (for houses); or
- An energy performance level that is at least 30% better than ASHRAE 90.1 (2007) for all other (non Part 9) buildings, which should be 55% better than the 1997 Model National Energy Code for Buildings.

This program will construct a total of 100 super-efficient residential units and an educational building by March 31, 2012 in both coastal and interior regions of British Columbia. ☼

Proposed Energy Efficiency Regulations for Residential Boilers

Natural Resources Canada is proposing to amend regulations to require more stringent energy efficiency regulations for residential gas and oil-fired boilers effective September 2010.

There have been no significant changes to minimum regulations since 1998. Advances in the combustion appliance technologies have generally boosted overall boiler efficiency already. The proposed new standards will apply to boilers with an input rating of less than 300,000 BTU/hr (88 kW).

Gas Hot Water: minimum 82% annual fuel utilization of energy (AFUE). As well, the unit will not be allowed to have a standing pilot light, and will need an automatic control to adjust water temperature.

Oil Hot Water: 84% AFUE. As well, the unit will need an automatic control to adjust water temperature. The use of the AFUE as the descriptor is a change, because current regulations call for seasonal energy utilization efficiency (SEUE), although most product literature now uses AFUE. In addition, the electrical energy consumption used for pumps and power burners for both gas and oil fired boilers will be taken into account.

These changes are seen as a preliminary step before implementing a mandatory requirement of 90% AFUE for gas boilers in the future. ☼

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CSA P.10-07 Standard

Performance Of Integrated Mechanical Systems For Residential Heating And Ventilation

CSA P.10 Performance Of Integrated Mechanical Systems For Residential Heating And Ventilation Standard was developed to meet the need for evaluating the performance of a new class of products that provide space heating, potable water heating, ventilation with heat recovery, and air circulation and distribution of fresh air as a single system.

The standard specifies procedures for evaluating the performance of the core functions of an integrated mechanical system (IMS) as well as the overall performance of the system. All of the tests are performed using the same basic test set-up and ambient temperature, and as a result, this standard includes new testing approaches and new metrics.

The committee drafting the standard wanted to establish testing and rating procedures for integrated mechanical systems that would permit products to be set up and operated under conditions comparable to those of actual operation. The conditions include a range of part-load heating conditions and allow the system controls to operate the IMS as they would in a house. This meant that they had to develop procedures that could be described independently of the individual technologies that could be incorporated into an IMS.

It also led to the development of test procedures for space heating that allow for part-load testing and rating of space heating performance based on load-weighted performance measurements. This is different from standard heating furnace tests that are done at full load, steady state conditions that in reality are seldom seen.

Many integrated mechanical systems are designed to operate their burners at a reduced input (or to cycle their burners) when they are operating to provide space heating, even when they are responding to a 100% call for heat (e.g., some have fixed-fire burners with outputs greater than the space heating coil capacities). This makes it impossible to use a rating method based on steady state measurements.

Two new overall performance descriptors consolidate the individual performances in each operating mode to provide annual thermal and electrical performance ratings. The overall thermal performance factor (OTPF) and annual electricity consumption (AE) are aggregate performance ratings based on the results of space heating, water heating, and ventilation performance tests.

OTPF accounts for the annual space heating, water heating, and ventilation loads. It is the sum of annual thermal outputs delivered by the IMS divided by the total thermal energy inputs needed to produce each component load.

AE accounts for the annual electrical energy used by an IMS to provide standardized space heating, water heating, and ventilation loads.

The minimum performance requirements for an IMS require that the OTPF be at least 0.78, and the AE, expressed in kWh, be a maximum of $(2820 + 70H_{CAP})$, where H is the full-load space heating output, expressed in kW.

A second performance level, called premium performance requires that the OTPF be at least 0.85, and the AE, be a maximum of $(1830 + 15H_{CAP})$.

The CSA P10 Standard was developed by CSA with the financial support of Natural Resources Canada (NRCan) and industry participation. ☼

R-2000

For information on the R-2000 Program, contact your local program office, or call
1-800-387-2000
www.R-2000.ca

Matrix: Integrated Mechanical System

The Matrix from NY Thermal Inc. is the first integrated appliance to qualify for the new CSA P.10 efficiency standard. The Matrix incorporates a condensing water heater, furnace and heat recovery ventilator, and is pre-wired for air conditioning.

The OTPF for the Matrix is 0.91, and the AE is 1826 kWh/y.

Compared to conventional natural gas furnaces and water heaters, a P.10-compliant system like the Matrix is 60 percent more efficient in heat recovery, 30 percent more efficient in water heating and is more efficient in space heating. It also uses considerably less electricity than the total consumption of the component appliances in a conventional configuration. It exceeds the minimum requirements for its "Premium" performance designation.

The Matrix is the first recipient of NRCan's new ēKOCOMFORT Award, which was presented at the 2008 CMX/CIPHEX show in Toronto.

For more information on the Matrix: www.ntimatrix.com.

Vancouver's Greenest City Initiative

What happens when local politicians set out to make their city the "greenest" city? In February 2009, the City of Vancouver launched the Greenest City Initiative with a goal for the city to earn that title by 2020. It has led the city to go beyond building codes to increase building performance.

The city has recognized that green building codes alone will not generate sustainable architecture and meaningful greenhouse gas reductions so it has adopted the Passive Design Program. The program was developed around two passive design toolkits: one is for homes, and one for larger comprehensive projects.

The Passive Design Toolkits (available for download at the City's web site) detail strategies for achieving energy efficiency and improved heating comfort through building design. The toolkits will serve as a resource to the development and design community, and will be used by the City's planning department to review and update its design guidelines.

Best Practices For Homes: Passive Design Toolkit was written by the Light House Sustainable Building Centre with Dr. Guido Wimmers to inform City staff and the design and development communities about passive design. While covering best practices, the toolkit is meant to address the specific needs of Vancouver and outline a definition of 'passive design'. Although it is focused on Vancouver, it can be used as a reference for best practices for design in any location, provided that local climatic and environmental issues are taken into account.

The principles of passive design are not new and are based on simple proven concepts. As presented in this document they draw on the German/Austrian PassivHaus standard, which has a maximum input energy of 15 kWh/m²/year for heating/cooling/ventilation, and a total primary energy use for all appliances, domestic hot water and space heating and cooling of less than 120 kWh/m²/year. Total primary energy includes the efficiency of the energy generating system so that hydro electricity would be more efficient than electricity generated in a coal burning power plant.

This performance target is significantly more aggressive than the current R-2000 target, although the proposed new R-2000 standard should be more in line with the European thinking.

Passive design refers to an approach that discourages reliance on mechanical systems for heating, cooling and lighting and instead takes advantage of the sun, wind and other climatic effects to maintain consistent indoor temperatures and occupant comfort.

Either the bias of the authors or their lack of awareness of Canadian construction means that there is a total neglect of recognition for the tools developed by the R-2000 program over the past 25 years. In fact, R-2000 is not even mentioned anywhere in the

document. Although the current R-2000 standard has its shortcomings, and is to be updated, without a doubt it has had a major impact internationally towards improving the energy performance of housing.

While this document provides a good design guide, it does have some significant shortcomings that may mislead some. It looks like there must have been a rush to publish the document, as adequate copy-editing and fact checking was not done.

The design discussion points out common recommendations that east, north and west window areas be kept small, and fewer windows be used in total. However, what is surprising for a design tool developed for use in Vancouver is the total disregard for one of the most important features of Vancouver – the North Shore mountains that are such a defining element for the city's setting. Designers in Vancouver face the constant challenge of reconciling the conflict between the million-dollar north facing views across the harbour toward the mountains, with the desire to capture solar gains on the south.

Another perplexing comment is that while the document acknowledges that Vancouver gets less than 2 ½ hours of sunshine in the winter, they go on to recommend not using low-e windows, although they encourage triple-glazed units.

Another perplexing discussion introduced is a discussion about urban heat islands. Every house, building and road changes the microclimate around it by increasing the temperature surrounding them, and this is known as an urban heat island. The larger the city, the greater the urban heat island effect, especially in the city centre, which can make the temperature within the city as much as 10°C higher than rural areas surrounding the city.

However, the heat island effect discussion is done in the context of a valuable discussion about the effect paint has on interior lighting, since light-coloured spaces look and feel brighter. The implication is left with the reader that light-coloured rooms will lower the urban heat island effect, which is patent nonsense. It is a stretch to suggest that light-coloured interiors in a home, which will help provide better daylight indoors, will have a major impact on the urban heat island effect. The short winter days with heavy overcast conditions and short winter days (at 49°N, winter daylight is less than 9 hours per day) will have a greater impact on artificial light use in homes.

An extensive insulation comparison chart was evidently not copy edited, because the typical insulation R-values for a few of the products listed are incorrect. In addition, straw bales are listed in the insulation products. Straw is not an appropriate material to use in the wet Vancouver climate, nor is it a local product.

In recent years, following the leaky condo crisis in coastal BC, designers and builders have become aware how building design can impact the durability of a structure. It was rediscovered that roof overhangs are an important element to protect the building envelope from moisture penetration – especially in a wet climate like Vancouver. In fact, the City was criticised, because for a period, in some building types areas under roof overhangs were considered as square footage leading to buildings with no roof overhangs and that led to many building envelope failures. So it is surprising how many images used in the document, including the cover art, show modernist home designs with no roof overhangs.

In some respects, it is almost as if the authors prepared this document as a universal passive design guide for use in all parts of the country, in which case it is doing a disservice to the intended audience in Vancouver. By definition, sustainable design must take into account local conditions. Regretably, the oversights in this document are significant.

Best Practices For Homes: Passive Design Toolkit. *Information:*
http://vancouver.ca/sustainability
http://vancouver.ca/greenestcity

Comings and Goings
Changes at NRCan

Generally, staff changes in a government department do not merit much attention. However, in the past few months there have been several changes that deserve mention. These folks were friends of the industry and had a significant hand in shaping the way we build today. Their retirement leaves a void.

Barbara Mullally-Pauly

Barbara retired early this year. She was the Senior Chief of Housing Programs for the Office of Energy Efficiency (OEE) at NRCan. A committed environmentalist, she has a lifelong dedication to efficient energy use. For years she lived on an off-grid farm with only a windmill to provide power, thus gaining a practical hands-on understanding of household energy systems.

She had lead roles in a variety of energy efficiency programs, but she is most proud of being involved in developing EnerGuide for Houses (EGH), a program that encourages homeowners to be energy-efficient in their home renovations.

Mark Riley

During a career spanning more than 30 years, Mark helped assure NRCan's leadership in clean energy technologies and innovation in the area of buildings and communities and, more recently, renewable energy technologies. Under his leadership, NRCan developed an outstanding portfolio of high-impact innovations that have set new levels of performance for energy efficient homes, buildings and communities. These included R-2000 Homes, Advanced Houses, C-2000 Buildings, Super-E Homes (Canadian housing export program), residential heat recovery ventilators, EkoComfort integrated mechanical systems, integrated design for buildings and communities, software, standards, technical guidelines and education materials.

Mark has been a champion of collaborations with other government departments, industry and academia, to establish new national facilities such as the Canada Centre for Housing Technologies. He has supported efforts to increase Canadian research and testing capacity with NRCan partners including the National Solar Test Facility, the Wind Energy Institute of Canada and the Laval Hydraulic Machinery Laboratory.

He has also been a strong proponent of international collaborations to accelerate the development of key technologies for Canada and to develop new markets for Canadian technology.

Mark Riley retired in April as S&T Director, Sustainable Buildings and Communities at CanmetENERGY.

Sylvain Quilliam

Sylvain was Chief, New Housing Programs at NRCan, and as such had oversight over the Energuide for New Houses program, R-2000, and other related programs that take advantage of NRCan Energuide Rating protocols. He was able to expand industry participation from the few committed builders ready to build more efficient homes to a broader segment of the industry through initiatives such as Build Canada, and supporting ERS adoption by regional energy efficient programs, with the result that NRCan's goal of achieving EnerGuide 80 by 2012 is now very real. Sylvain has accepted a new position at Industry Canada.

In Memoriam

Tony Woods
Building Envelope Guru Passes Away

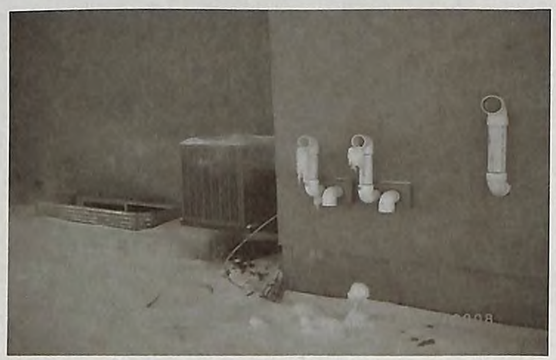
Tony Woods, the founder of Canam Building Envelope Specialists and Zerodraft®, left a significant mark on Canadian building performance. Woods spent decades developing ways to diagnose building envelope flaws, established methods of calculating potential energy savings from leakage control work, and launched a line of weatherization products. He passed away on May 8, after a battle with cancer.

Side wall vented gas appliances

Regular readers will know that we have been championing a review of gas standards, and specifically the detailing of terminations for natural gas appliances. With the move to high efficiency combustion appliances, the allowable venting has changed, recognizing that a plastic vent can be vented out the sidewall of a building because of the low temperature of the vent gases. For many, the sidewall venting of these appliances is attractive and economical since there is no need for special flues. However, as we've pointed out, the moisture content in the flue gases is significant, and can lead to problems.

We seem to be living in an age when sometimes doing the right thing is difficult to do until we're hit over the head. One of these days a smart lawyer somewhere will find a way to make a case over this with the result that the hullabaloo will spur regulatory action.

A reader sent us this photo of a gas vent termination, which is code compliant, for a gas furnace that was retrofitted into an older Winnipeg house. We suspect that the neighbour is not amused. Who knows what sort of potential damage this could be doing.



This is another example of sidewall vented furnace and water heater. The ice build-up is an indication of the amount of moisture in the flue gases. When it does not freeze up, where does the steam end up? This house is in Calgary. The ice build-up on the vent pipes is obvious. The moisture from these can also migrate into the attic through soffit venting.

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R-4 Insulsheathing: Insulated Sheathing

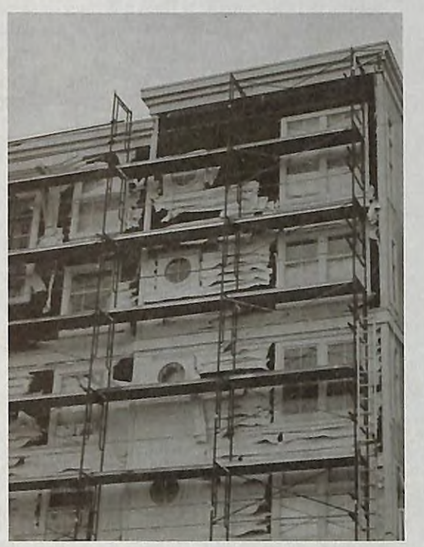
Low-density fibreboard is a panel produced from non-toxic organic materials and natural wood fibres. The panels are asphalt coated for greater weather resistance and face outward. Wood fibre sheathing panels have excellent water vapour permeability that allows water vapour migration through to avoid trapping moisture within the wall cavity. It is widely used as a sheathing material in Eastern Canada.

Building Products of Canada has launched R-4 Insulsheathing in Quebec. It is a new composite structural insulating panel – one part is low-density fibreboard, the second is expanded polystyrene insulation.

The 4'x9' panels have a 7/16" thick fibreboard layer with a 11/16" expanded polystyrene layer on the inner side. The total panel provides a nominal R-4 insulating value, which helps reduce thermal bridging through framing.

Diagonal deformation tests performed by CRIQ (Centre de Recherche Industrielle du Quebec) showed that the panel is 20% stronger than the conventional black-coated fibreboard sheathing (which meets the national building code standards for sheathing), but slightly lower than their Excell II panel.

Currently R-4 Insulsheathing is only being marketed in Quebec.



Vinyl Siding

Radiant heat flow is powerful. This is the vinyl siding on the building, the result of a fire across the lane, and about 500 feet away.
The effect of radiation shielding is evident – the wall faces not exposed to the fire are in pristine condition, while those in the direct line of sight shows deformed and melted siding.

Energy Answers

Letter from London

Rob Dumont

For this column I am writing some observations from a recent trip through London, England.

England has an international reputation for inertia and slowness. One joke going round is that in Britain there are only two speeds: slow and never. The nation has a 'stiff upper lip' that can tolerate inaction for a very long time.

Winston Churchill, in his book "While England Slept" lamented the inertial state of his country in the 1930s in the face of the growing military build-up in Nazi Germany. Fortunately, England was able to shake off its torpor, and, along with its allies, eventually defeated the Nazis. Had England been prepared, it is likely some 50 million deaths could have been avoided.

England has had a similar problem with inertia in its energy use. Historically its buildings have been very poor energy performers compared with the Scandinavian ones. British buildings were infamous for their leaky single glazed windows, walls with no insulation, inadequate roof insulation, inefficient heating systems, poor air barriers – the list goes on.

However, the inaction is now over. While in London for a week in May 2009, I was impressed with a number of building initiatives under way. As mentioned in an earlier column, Britain has decreed that all of its new houses must be carbon neutral by 2016. (And here in Canada, many provinces don't even have a residential energy code!)

All of Britain's public buildings have had energy audits done, and all the buildings are ranked with an energy consumption label. For instance, while visiting the British Library, I noticed a sign that listed the energy consumption of the library along with a comparative ranking of the building. The building was rated as using 255 kilowatt-hours of energy per square metre per year. For comparison, a typical building of this type was using 243 kilowatt hours per square metre per year in Britain.

These are not 'puff' ratings. I know from personal experience how challenging it is to reach 25 kWh/m² per year. The Factor 9 Home came in at 33 kWh/m² per year, and my own house at 47 kWh/m² per year in Saskatchewan's climate.

The British Library admitted that its performance was disappointing, and has committed to improving its performance.

The sign also had a ranking of buildings. The ranking was as follows:

A	0 to 25 kWh/m² per year
B	25 to 50
C	50 to 75
D	75 to 100
E	100 to 125
F	125 to 150
G	Greater than 150

Here in Canada we have no such rating scheme for public buildings. Unlike Canada, Britain has met its Kyoto target. Canada is likely to be 30% over its Kyoto target by 2012.

Another energy related area where Britain is well ahead of Canada is in the transport area. Here are some of the innovations I saw in London.

1. Dedicated bus lanes throughout the city where private cars are banned.
2. Congestion charges in the inner city to discourage private auto use during peak hours from Monday to Friday. Stiff surcharges are levied on private cars that drive into the inner city during those times.
3. Excellent public transport to the main airport – Heathrow. An inexpensive subway ticket will get you a ride on the Piccadilly Line out to Heathrow. An even faster way is via the Heathrow Express train from Paddington Station. Canada's largest city, by contrast, has no subway line or train direct to the airport. Only Vancouver will have a train (part of the city's subway system) direct to the airport starting later this year.
4. A new Eurostar high speed train (300 km/hr peak speed) from London's St. Pancras Station (served by 5 subway lines and numerous bus routes) to Paris or Brussels in just over 2 hours.
5. Gasoline (petrol) prices that were about $1.60 Canadian per litre at a time when Canadian prices were about $0.90 per litre. SUVs and light trucks – so common in many parts of Canada – are an infrequent sight in London.
6. A very convenient pre-paid smart card system called the OYSTER that allows you to pay for your bus or subway fare by merely tapping the card on a pedestal. The OYSTER card also gives you a cheaper rate after 9:30 a.m. weekdays to encourage travel at off-peak times.
7. Economical bus fares. In Central London the bus fare was only about $1.80 Canadian after 9:30 a.m.

Britain used to be called part of the 'Old Country', in part because of its slowness to adapt. Is Canada, with its inertia on energy matters, such as its Alice-in-Wonderland 'intensity based targets' becoming a new 'old country'? ☼

You Asked Us: About Finishing a Basement Bathroom

We are close to insulating a house with a walkout basement, and are having a debate over whether or not to vapour barrier a bathroom downstairs, with mostly concrete foundation walls. The floor has radiant heat in the insulated concrete floor.

I have been led to believe that a vapour barrier is not used in the situation that we have, where the house backs into the slope so that the wall is a full concrete wall. My understanding is that moisture will be coming through the concrete and must be able to dry into the living space.

The stud wall is 1 inch off the concrete, so there is no direct contact. A corner of this basement has a full bathroom, and we are told that this space should have a vapour barrier to prevent excess moisture from the bathroom migrating into the wall space and deteriorating the stud wall.

The bathroom has an opening window, and we are installing a heat recovery ventilator system. I am assured that this will handle the excess bathroom moisture, although other contractors and the electrical contractor are saying that HRV systems aren't handling the moisture and are going back to add additional bathroom fans.

The construction assembly must be air tight, and you still need a vapour barrier, but the vapour barrier should not be polyethylene – it should have a slightly more permeable vapour barrier. You have two options for finishing the wall. One could be to apply spray foam insulation directly against the concrete, to fill the furring with the desired insulation level. The second would be to place 1" of rigid insulation directly against the concrete wall and the furring can go directly against it, with added batt insulation in the cavity. There should be no cavity behind the wall studs.

If you are using a closed cell (two-pound) polyurethane spray foam as insulation, then the vapour barrier protection is the spray foam itself. If you use an open cell (half-pound) foam (such as Icynene) or the rigid foam plus fibreglass batt, then the vapour barrier to use would be a vapour barrier paint on the drywall (it's available as a drywall primer).

This minimizes the vapour diffusion into the wall, but also permits moisture to dry into the conditioned space, rather than building up against the backside of the poly. However, finished insulated basement walls should avoid poly.

Since you are installing an HRV, it should provide all the ventilation required. If it is not moving enough air then it has not been installed correctly. With properly designed and installed ductwork, the HRV should move the same amount of air (if not more) as a separate bathroom fan would when the HRV is turned on to high speed. The key point about HRVs is that they are running constantly, so when even when it reverts to slow speed, it will still be moving air out of the bathroom, while the bath fan simply shuts off and does nothing.

An opening window is irrelevant to the discussion because it won't do much in terms of removing moisture or odours most of the time, assuming the window will be opened!

With all due respect to the electrical contractors, they are not trained in the dynamics of airflow, so should not be designing ventilation systems. Most will not be aware that the typical way bathroom fans are installed they only move half the rated airflow. ☼

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Nanoscience for Greener Concrete

By Taijiro Sato

The cement industry is seeking ways to reduce the energy and resource consumption of concrete, the most widely used building material. Presently, the manufacture of one tonne of cement requires about 1.5 tonnes of raw materials and releases about 1 tonne of CO_2.

It has been known for some time that the use of supplementary cementitious materials (SCMs) as a partial replacement for ordinary Portland cement (OPC) in concrete can reduce its environmental load. The use of substantial volumes of SCMs reduces CO_2 emissions and saves energy and natural resources. However, high volumes of SCMs, including fly ash and slag, delay the early hydration of OPC and slow down the initial strength development of concrete. This can be a major disadvantage in situations where delayed curing adversely affects construction scheduling.

To reduce the environmental effects of concrete without extending curing time, the National Research Council Institute for Research in Construction (NRC-IRC) initiated a study on the use of nano-calcium carbonate (nano-$CaCO_3$) as an accelerator for hydration of OPC delayed by high volumes of SCMs.

The reaction between OPC and water results in heat development. A conduction calorimeter was used to measure the rate of this heat development as a function of time, indicating how quickly or how slowly hydration takes place.

The rate of heat development of OPC hydration is shown in Figure 2 for: OPC Control; OPC containing fly ash; and OPC containing fly ash with the additions of micro- and nano-$CaCO_3$. The contents of fly ash and both micro- and nano-$CaCO_3$ were 50% and 20%, respectively based on the total mass of OPC and fly ash.

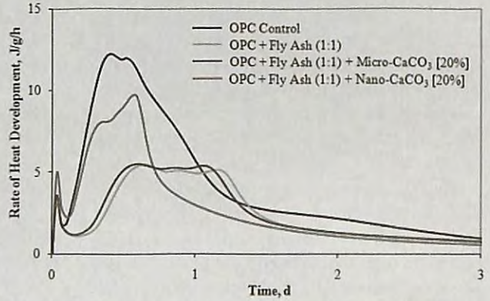


Figure 2: Rate of heat development determined by the conduction calorimeter

Current IRC Work

The NRC-IRC study compared the effects of two different types of $CaCO_3$ – micro-$CaCO_3$ and nano-$CaCO_3$ — on the hydration of OPC. Scanning electron microscope images of both sizes of $CaCO_3$ are shown in Figure 1, with respective magnifications of 5000× and 50,000×. The average particle size of the micro-$CaCO_3$ is about 100 times larger than that of the nano-$CaCO_3$.

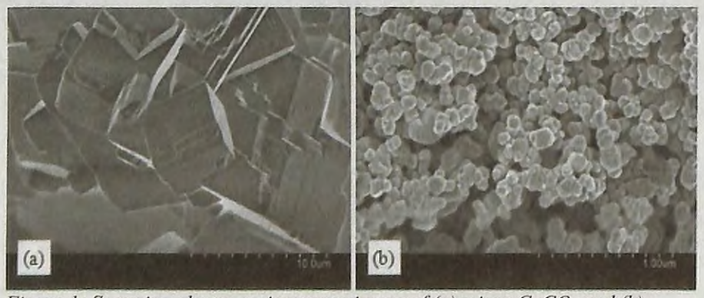


Figure 1: Scanning electron microscope image of (a) micro-$CaCO_3$ and (b) nano-$CaCO_3$

The result indicates that the rate of heat development of hydration of OPC was significantly delayed by high volumes of fly ash. When micro-$CaCO_3$ was added to the OPC/fly ash blend, the rate of heat development was slightly accelerated above that without micro-$CaCO_3$ addition. When the nano-$CaCO_3$ was added to the blend, the rate of heat development was significantly accelerated.

In order to understand the mechanism of this accelerating effect, a thorough scanning electron microscope (SEM) study was also conducted. Figure 3 shows the SEM image of the surface of the hydrated OPC with the addition of nano-$CaCO_3$. It clearly shows that the C-S-H (calcium silicate hydrate, the most important hydration product) grows around the nano-$CaCO_3$ particle, suggesting that the addition of nano-$CaCO_3$ enhances the nucleation of C-S-H, and therefore accelerates the hydration of OPC.

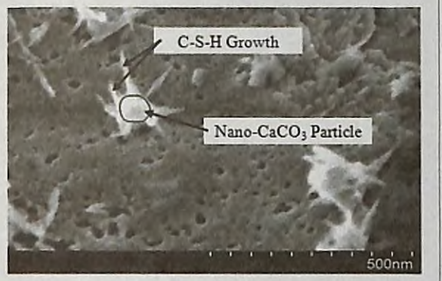


Figure 3: SEM image of C-S-H growth around a nano-$CaCO_3$ particle

Future Work

The present research confirms previous indications that the addition of nano-$CaCO_3$ to mixtures with SCMs improves the rate of hydration and that the finer the $CaCO_3$, the faster the rate of hydration.

Thus far, NRC-IRC has focused on studying the effect of the addition of nano-$CaCO_3$ on cement paste containing SCMs. The next stage will extend the research to concrete mixes typically used in construction.

In addition to testing of concrete materials, special attention will be given to several other practical aspects that require examination. The dispersion of nano-$CaCO_3$ within cement paste is one of them. The nano-particles tend to stick together. Adequate dispersion of nano-$CaCO_3$ can maximize the accelerating effect at lower dosage. Another aspect to investigate is the effect of the addition of nano-$CaCO_3$ on concrete workability.

☼

Taijiro Sato, PhD, is a research associate in the Building Envelope and Structure program of the NRC Institute for Research in Construction (NRC-IRC). He can be contacted via e-mail at taijiro.sato@nrc-cnrc.gc.ca.

Net-Zero Energy Home (NZEH) Awards

To help advance the market and accelerate the deployment of net-zero energy homes in Canada, the Net-Zero Energy Home (NZEH) Coalition has developed the Net-Zero-Energy Home Award to recognize and celebrate the integration of renewable energy and energy efficiency in the residential construction industry.

A net-zero energy home integrates advanced energy efficiency design and building materials with onsite renewable energy, which is then capable of producing an annual output of energy that is equal to the total amount of its annual purchased energy.

The inaugural Net-Zero Energy Home (NZEH) Awards were presented in Montreal, June 8, 2009. Awards were given under four categories:

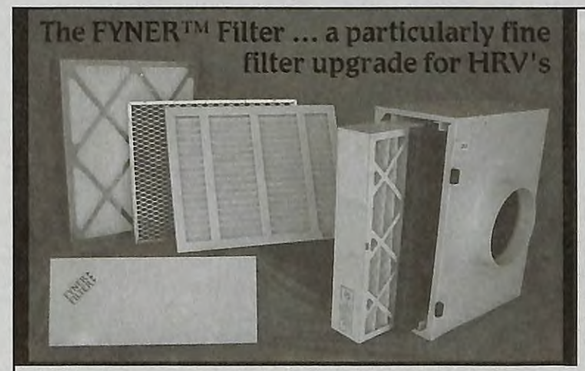
Closest to net-zero energy retrofit project of the year: Now House Project in Toronto. This was one of CMHC's Equilibrium projects.

Closest to net-zero energy custom builder of the year: Habitat Studio & Workshop Ltd. of Edmonton.

Closest to net-zero energy production builder of the year: EcoCité Developments of Montreal.

Net-Zero Energy Home champion of the year: Derek Satnik of Mindscape Innovations Group Inc. of Kitchener, ON.

The FYNER™ Filter ... a particularly fine filter upgrade for HRV's



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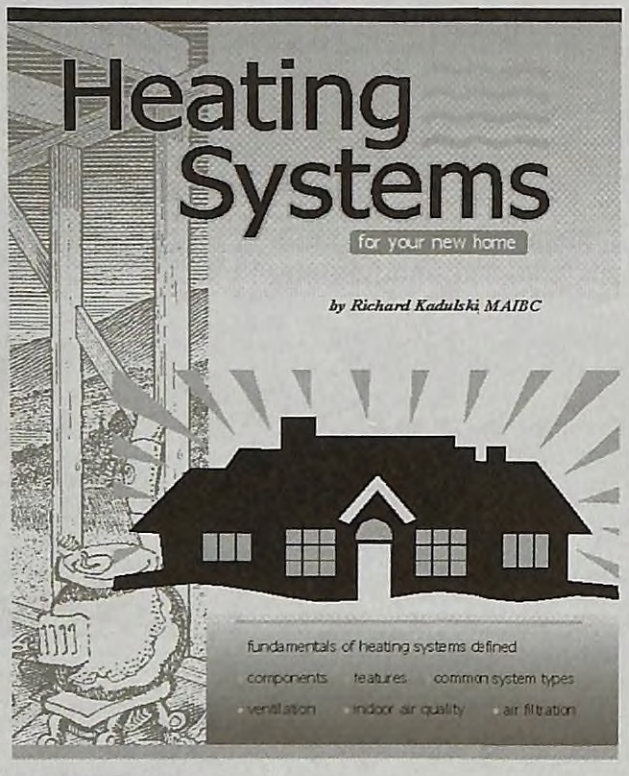

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